

Utilisation of Acoustics for Monitoring Local and Near-Field Mine Burial Processes: Proof-of-Concept

Peter D. Thorne

Proudman Oceanographic Laboratory, Bidston Observatory, Bidston Hill, Prenton,
Merseyside CH43 7RA, UK

Phone: +44 (0)151 6538633 Fax: +44 (0)1521 6536269 e-mail: pdtd@pol.ac.uk

Award Number: N00014-01-1-0549

<http://www.mbp.unh.edu/front/index.cfm>

LONG-TERM GOALS

The goal of the Proudman Oceanographic Laboratory's, POL, contribution to the Mine Countermeasures Programme, is to assess the applicability of recent developments in the application of acoustics, to the high resolution measurement of sediment processes, in the context of its utilization for advancing our understanding of mine burial.

OBJECTIVES

The objectives for POL's research for 2002/3 were:

- (i) To calibrate an OMNI mine surface mounted acoustic transceiver system to be used for flow, suspended sediment and burial measurements.
- (ii) Participate in the Santa Cruz experiment in March 2003 on near bed sediment processes.
- (iii) Complete the work on the scattering properties of suspensions of sands and prepare a journal paper on the results
- (iv) Analyze some of the acoustic mine data from the Tampa Bay experiment.

APPROACH

To interact with collaborators OMNI technologies and NRL Stennis. This was primarily carried out through email, exchange of papers and a visit in the Fall of last year by Sean Griffin (OMNI) and Mike Richardson (NRL) to POL. It was also anticipated that some data exchange would take place this year. Through discussions with David Cacchione, POL joined in the Santa Cruz Experiment in March 2003 and provided an acoustic backscatter system, ABS, for suspended sediment measurements. Final analysis was to be conducted on the POL sediment tower data on sediment scattering and a manuscript prepared on the data.

WORK COMPLETED

Calibration of the OMNI acoustic system was carried out at POL in September 2002. This was conducted in the POL sediment tower and measurements on suspensions of sediments were taken. The results were used to modify the OMNI acoustic systems in preparation for the experiment in Tampa Bay in early 2003, when four instrumented mines were deployed.

In March 2003 a process studies experiment was carried out as part of the Mine Burial field experiment off the main pier at Santa Cruz. POL joined in this experiment and deployed one its ABS's

| Report Documentation Page | | | | Form Approved OMB No. 0704-0188 | |
|--|------------------------------------|-------------------------------------|---|---|---------------------------------|
| Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. | | | | | |
| 1. REPORT DATE 30 SEP 2003 | | 2. REPORT TYPE | | 3. DATES COVERED 00-00-2003 to 00-00-2003 | |
| 4. TITLE AND SUBTITLE Utilisation of Acoustics for Monitoring Local and Near-Field Mine Burial Processes: Proof-of-Concept | | | | 5a. CONTRACT NUMBER | |
| | | | | 5b. GRANT NUMBER | |
| | | | | 5c. PROGRAM ELEMENT NUMBER | |
| 6. AUTHOR(S) | | | | 5d. PROJECT NUMBER | |
| | | | | 5e. TASK NUMBER | |
| | | | | 5f. WORK UNIT NUMBER | |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Proudman Oceanographic Laboratory, Bidston Observatory, Bidston Hill, Prenton,,Merseyside CH43 7RA, UK, , , | | | | 8. PERFORMING ORGANIZATION REPORT NUMBER | |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) | | | | 10. SPONSOR/MONITOR'S ACRONYM(S) | |
| | | | | 11. SPONSOR/MONITOR'S REPORT NUMBER(S) | |
| 12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited | | | | | |
| 13. SUPPLEMENTARY NOTES | | | | | |
| 14. ABSTRACT | | | | | |
| 15. SUBJECT TERMS | | | | | |
| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT Same as Report (SAR) | 18. NUMBER OF PAGES 6 | 19a. NAME OF RESPONSIBLE PERSON |
| a. REPORT unclassified | b. ABSTRACT unclassified | c. THIS PAGE unclassified | | | |

for the measurement of suspended sediments. Pre-calibration and post-calibrations were carried out on the system in the POL sediment tower and a consistent calibration obtained. Data were collected with the ABS over the deployment period amounting to approximately 330 MB. Provisional inspections of the data show useful measurements were obtained and these need to be processed to obtain suspended sediment parameters.

Final interpretation of the data collected in the POL sediment tower was carried out, this concluded a program intermittently spanning a number of years to analyze the scattering properties of suspensions of sands. A manuscript was prepared and has been submitted to a journal.

Analysis of the acoustic data from the instrumented mines has yet to take place. An extremely large amount of data was collected and the data is being organized for interpretation.

RESULTS

Santa Cruz. Provisional results from the Santa Cruz pier experiment from March 2003 are presented¹. The instrument rig used to collect the data is shown below.

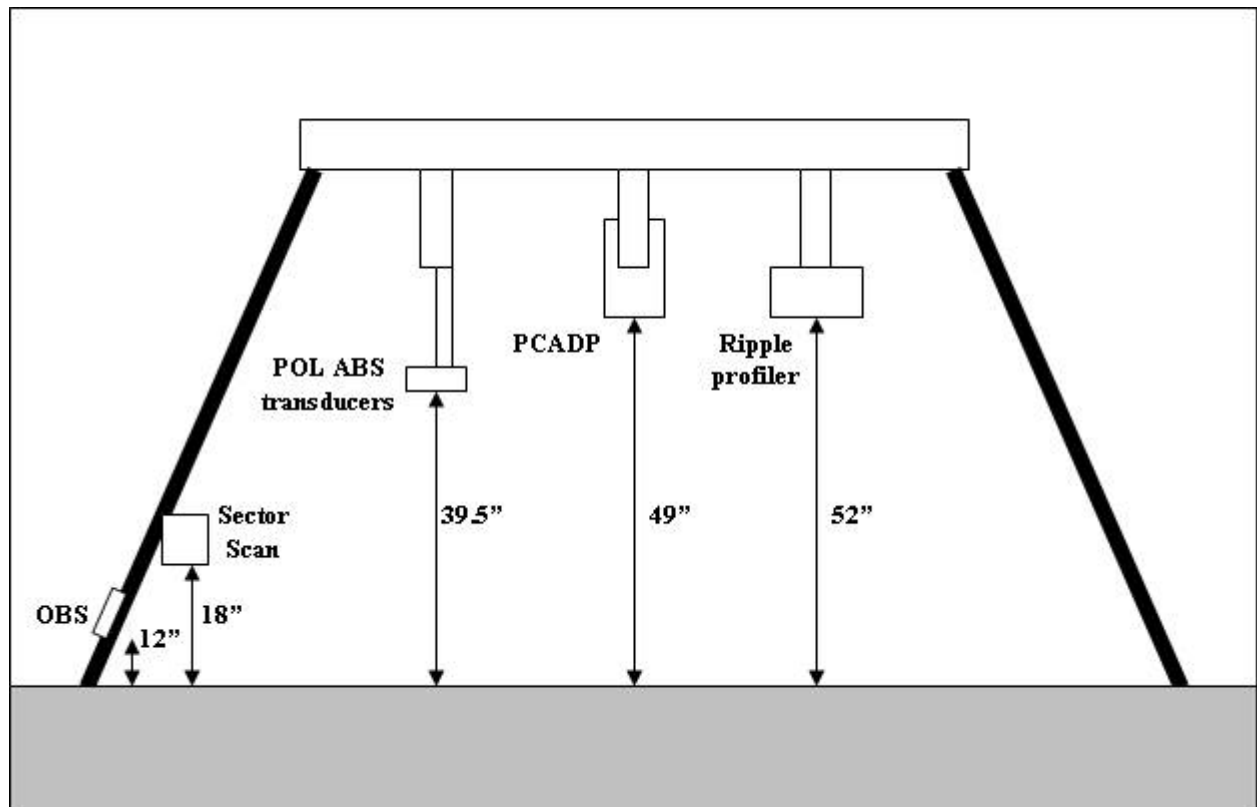


Figure 1. Side view of the Santa Cruz sediment processes rig. The instruments used are shown relative to their height above the bed.

Optical backscatter, OBS, and acoustic backscatter, ABS, were used to measure the suspended sediments. The OBS provides a single height measurement of the concentration and the ABS can provide profiles of the mean particle size and concentration. To monitor the bedforms and their variation over time an acoustic ripple profiler, ARP, and a sector scanning sonar, SSS, were used. The ARP provides measurements of the wavelength and height of the bedforms along a transect and the

SSS gives detailed images of the bed over an area. To measure the flow a pulse coherent acoustic Doppler profiler, PCADP, was used. The PCADP provided profiles of the three orthogonal components of flow up to a maximum sampling frequency of 2 Hz.

Below is given an example of the data collected using the ABS, which operated at 0.7 MHz, 2.0 MHz and 4.0 MHz. The figure shows an example of the logarithm of the recorded voltage over a range of 1.28 from the transducer, for one of the recording period of approximately 1300s.

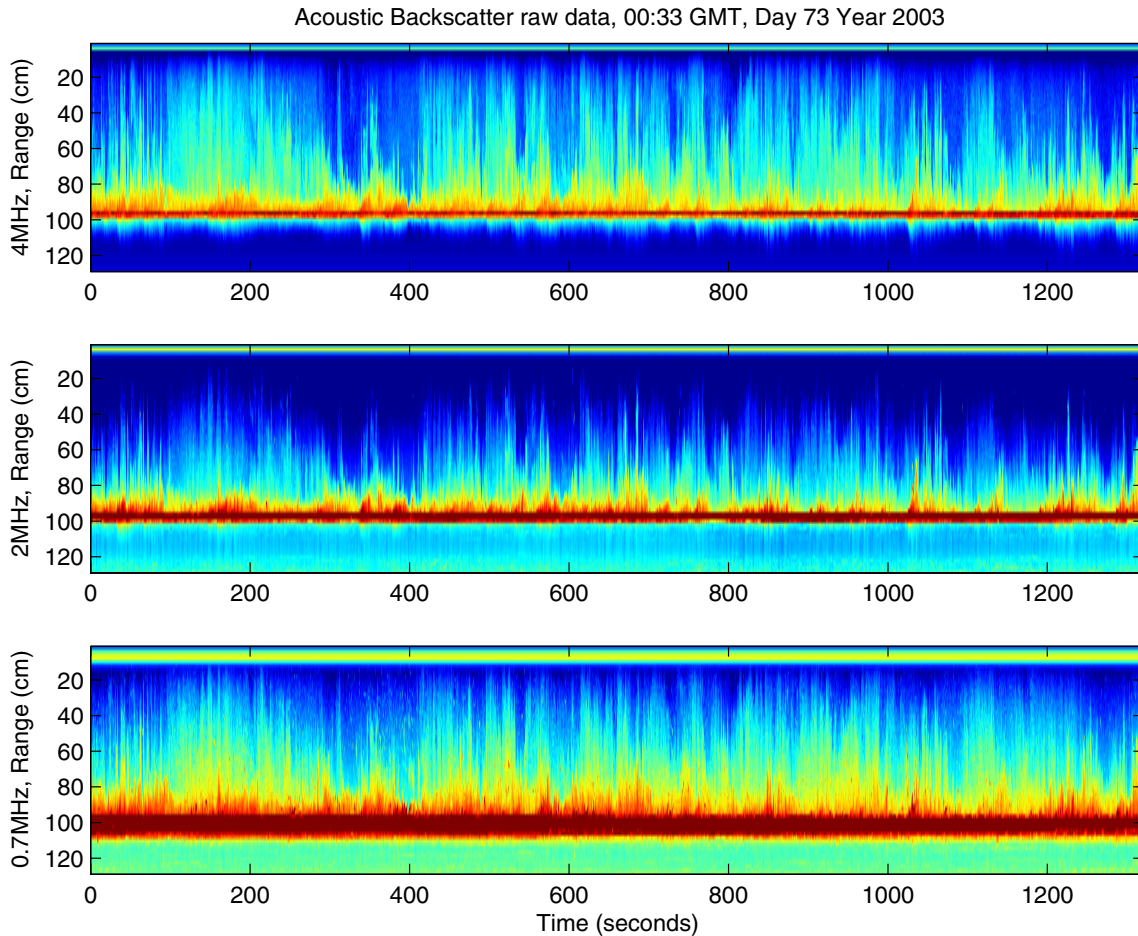


Figure 2. Records of the ABS backscattered signal with range from the transducers at the three operating frequencies.

Although the data in Figure 2 does not provide quantitative measurements of the suspended sediments (calibrations and inversions need to be applied to obtain absolute sediment parameters), the data clearly shows similar features. Firstly the light band between approximately 0.0 m - 0.1 m from the transducers is associated with transmit breakthrough, this is an artifact of the system and not sediment related. The dark band running along the records at approximately 1 m is the echo from the bed; therefore the bed location can be readily identified. The variation in color between 0.1 m - 1.0 m is due to variations in suspended sediment concentration and particle size. The patterns of color variation in this region are comparable and this consistency in color variation between the three frequencies is indicative of a relatively consistent data set. The next stage in this work is to apply calibrations and inversions to obtain suspended sediment concentration and particle size.

Instrumented mines. Calibration of one of the surface mounted transducer systems was carried out at POL in the sediment tower. Both acoustic and electronic modifications were made to the system following measurements made on suspensions of sediments in the sediment tower. The calibrations were required for setting the gain and sensitivity of the OMNI system. Analysis and processing of the acoustic data is intended to begin in the near future.

Sediment scattering measurements. Measurements of the scattering properties of suspended sediments were reported in the 2002 ONR report. The data has been reanalysed and a somewhat different interpretation used to explain the observations². Using a sphere based model, with enhanced scattering characteristics dependent on the wavenumber, k , of the sound in water and the sphere radius, a_s , a generic function has been developed which describes the backscattering and attenuation characteristics of suspensions of marine sands. An example of the results is given below.

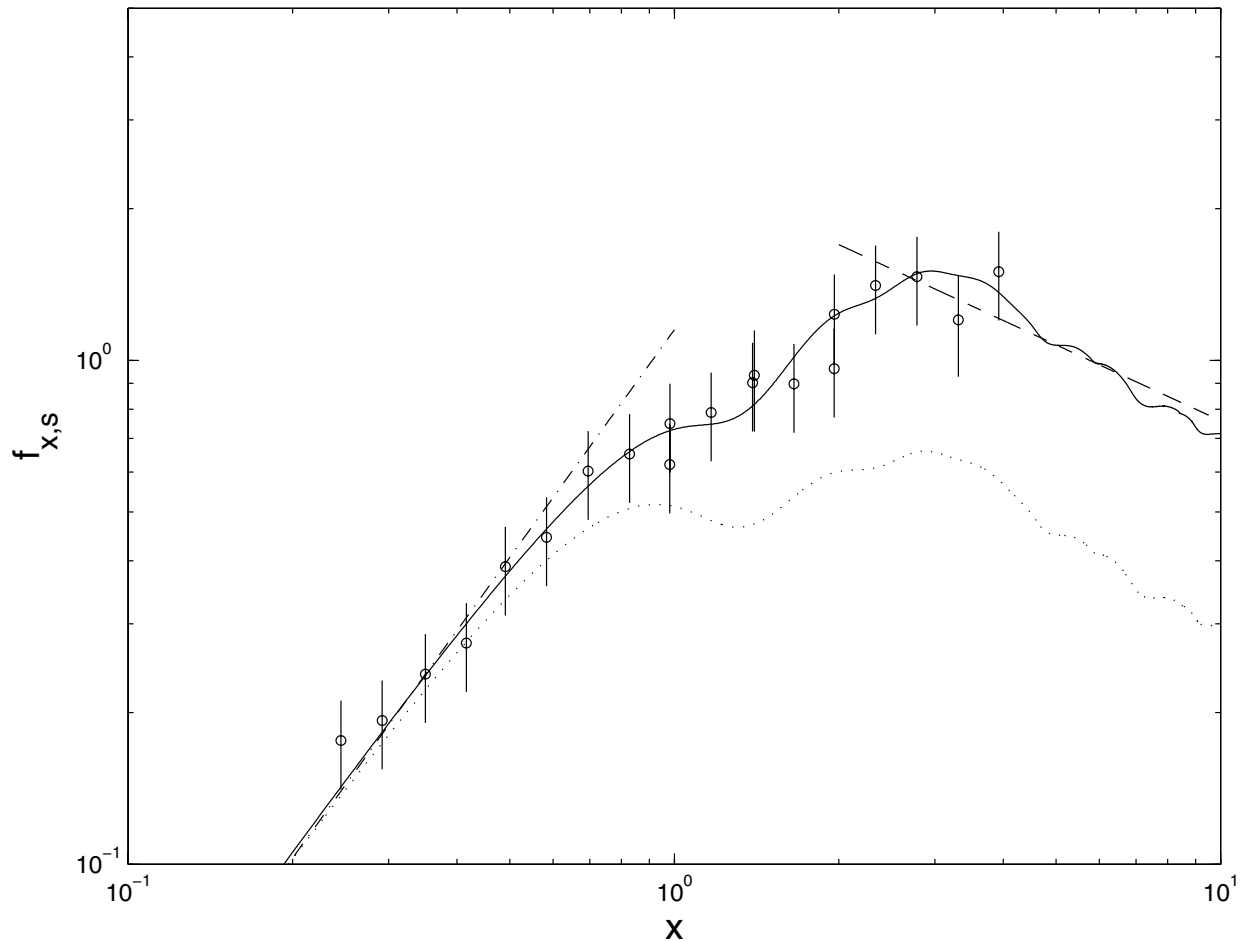


Figure 3. Measurements of the backscattering characteristic of a suspension of sand compared with sphere based models. (.....) Sphere scattering. (—) Modified enhanced sphere scattering model.

The results in figure 3 show that at low values of x , ($x = ka_s$) the scattering properties of sediments are similar to a sphere. As x increases there is greater divergence between the sphere scattering and the data. Above $x > 3$, the difference in level remains constant. Using the modified enhanced sphere scattering model provides a much-improved description of the sediment scattering properties.

IMPACT/APPLICATIONS

The work reported here will be used to interpret the data collected by the acoustic systems on the OMNI mine. The sediment scattering measurements and modelling will be used to extract sediment parameters from the acoustic data collected by the surface mounted transducers. The physical process study from the Santa Cruz experiment will be used to guide the interpretation of the sediment dynamics derived from the acoustic data.

RELATED PROJECTS

POL's Program 2 Theme 5; 'Process experiments at small scale in shallow seas'

<http://www.pol.ac.uk/home/research/p2t2prcx.html>

REFERENCES

1. Cooke R. Field ABS unit deployment report. ONR mine burial project. Santa Cruz California, USA. March 2003. Internal report pp10.
2. Thorne P. D. and Buckingham M. J. Measurements of the form function and total scattering cross section for suspensions of sands. J Acoust. Soc. Amer. 2003 (submitted refereed)

PUBLICATIONS

- Thorne P. D., Williams J.J. and Davies A. G. Suspended sediments under waves measured in a large-scale flume facility. J. of Geo. Res., 107, C8, 10.1029/2001JC00988, 4.1-4.16, 2002. (published, refereed).
- Williams J.J., Bell P.S. and Thorne P.D. Field measurements of flow fields and sediment transport above a rippled bed. J. of Geo. Res. 108, C4, 10.1029/2002JC001336, 6.1-6.35, 2003. (published, refereed).
- Williams J.J., Bell P.S., Betteridge K. and Thorne P.D. Transport of coarse sand by tidal currents and wave. Proceedings of Coastal Engineering 2002, held in Cardiff, UK 7-12 July 2002. 3007-3019 (published).
- Thorne P. D., Davies A.G. and Williams J.J. Measurements of bedforms and sediments in suspension under waves. Proceedings of Coastal Engineering 2002, held in Cardiff, UK 7-12 July 2002. 3065-3077 (published).
- Davies A.G. and Thorne P. D. 1DV-model of sand transport by waves and currents in the rippled bed regime. Proceedings of Coastal Engineering 2002, held in Cardiff, UK 7-12 July 2002. 2599-2611 (published).
- Thorne P. D., Davies A. G. and Williams J.J. Measurements of near-bed intra-wave sediment entrainment above vortex ripples. Geophysical Research Letter. 2003. (In press refereed).
- Thorne P. D. Application of acoustics to nearbed marine sediment transport processes. Where are we? Proceedings of the tenth international congress on sound and vibration. Held in Stockholm 7-10 July 2003, Vol 5, 2651. (published)
- Thorne P. D., Davies A. G. and Williams J. J. Measurements of intra-wave sediment entrainment over a rippled bed. Proceedings of Coastal Sediments'03 held in Clearwater Florida, USA 18-23 May 2003. Published on CD-rom. 1-7. (published).

- Williams J. J., Bell P. S., Betteridge K. F. E. and Thorne P. D. Laboratory study of wave-sediment interaction at field-scale. Proceedings of Coastal Sediments'03 held in Clearwater Florida, USA 18-23 May 2003. Published on CD-rom. 1-13. (published).
- Thorne P. D. and Buckingham M. J. Measurements of the form function and total scattering cross section for suspensions of sands. J Acoust. Soc. Amer. 2003 (submitted refereed).